# PRINCIPAL FACTS FOR GRAVITY STATIONS IN THE VICINITY OF COYOTE SPRING VALLEY, NEVADA, WITH INITIAL GRAVITY MODELING RESULTS

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## ABSTRACT

Gravity measurements were made along 5 profiles across parts of the Coyote Spring Valley and vicinity in order to aid in modeling the depth and shapes of the underlying basins and to locate faults concealed beneath the basin fill. Measurements were taken at 200 m (660 ft) spacing along the profiles. Models based on these and existing regional data reveal two north-south-trending basins beneath Coyote Spring Valley that reach maximum depths of greater than 1 km (0.6 mi). A small valley, located just east of Coyote Spring Valley and containing Dead Man Wash, includes a small basin about 500 m (1600 ft) deep that appears to be the southern continuation of the northern basin beneath Coyote Spring Valley. The profile gravity data are further used to identify the locations of possible faults concealed beneath the basin fill.

## INTRODUCTION

At the request of the Southern Nevada Water Authority, the U.S. Geological Survey conducted a gravity survey in the Coyote Spring Valley and vicinity, Clark and Lincoln Counties, Nevada, during May, 2000. The purpose of the survey was to help define the shapes of young basins filled with Cenozoic rocks and alluvium, and to identify any possible faults within these basins that might influence the movement of groundwater. The gravity measurements were taken along detailed profiles crossing the southwestern end of Kane Springs Valley, parts of Coyote Spring Valley, and the small valley (located 25 km (15 mi) WNW of Glendale and Moapa, NV) just east of Coyote Spring Valley that contains Dead Man Wash and a section of Pahranagat Wash (fig. 1).

Coyote Spring Valley is a north-south-trending valley about 80 km (50 mi) north of Las Vegas, NV. The valley areas containing the gravity profiles are bounded on the west by the Sheep and Las Vegas Ranges, on the north by the Delamar Mountains, and on the east by the Meadow Valley Mountains. The Arrow Canyon Range projects from the south into the southernmost gravity profiles (figs. 1 and 2).

The valleys in the study area were created by Miocene extension of the crust that formed the basins and ranges that make up most of Nevada today (Stewart, 1980). The ranges

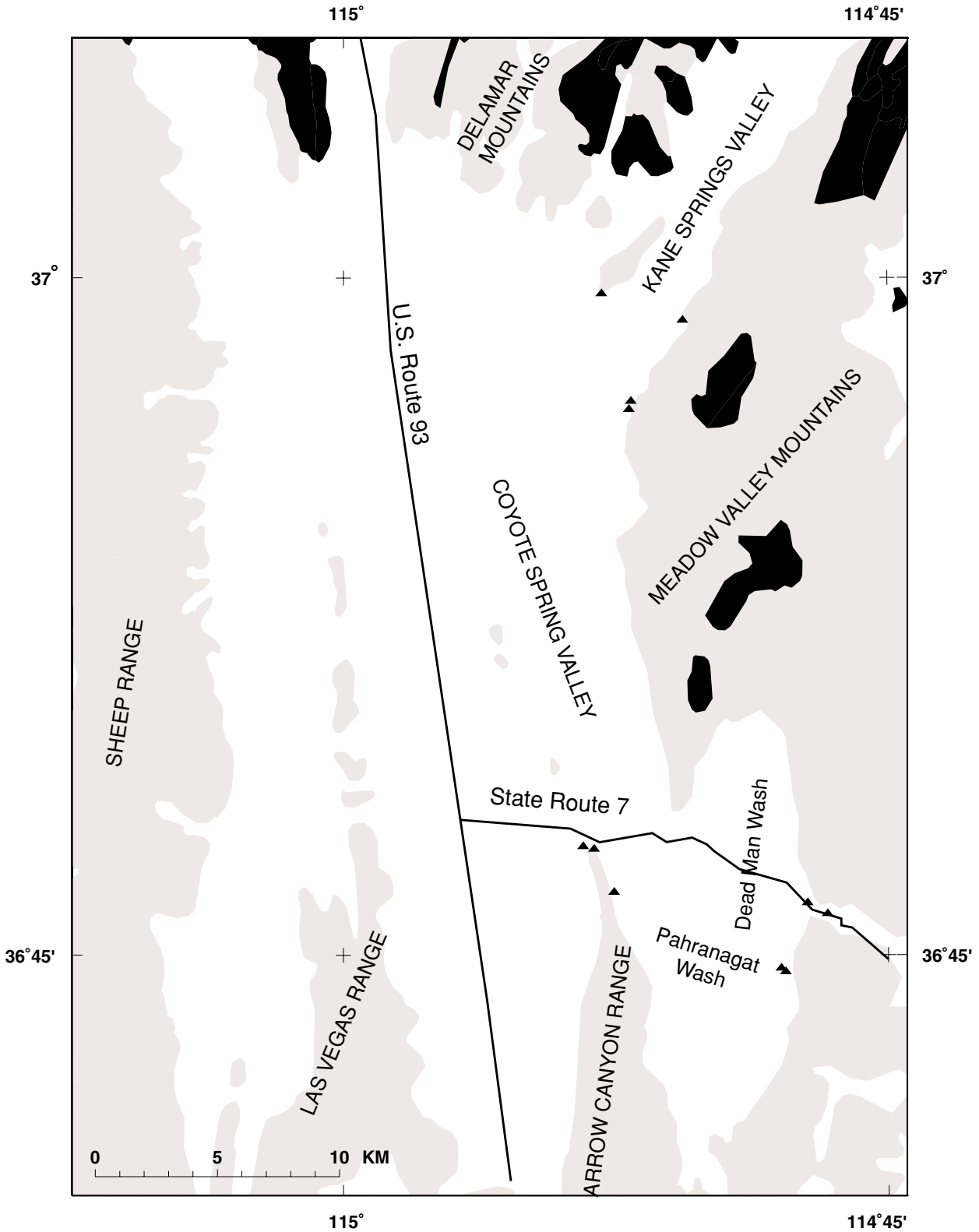



Figure 1. Index map showing Coyote Spring Valley study area and vicinity, Nevada. Black areas have outcrops of Cenozoic volcanic rocks, gray areas have outcrops of Paleozoic rocks, and white areas indicate areas covered by Cenozoic basin fill. Solid triangles indicate locations where samples of Paleozoic rock were collected for density measurements.

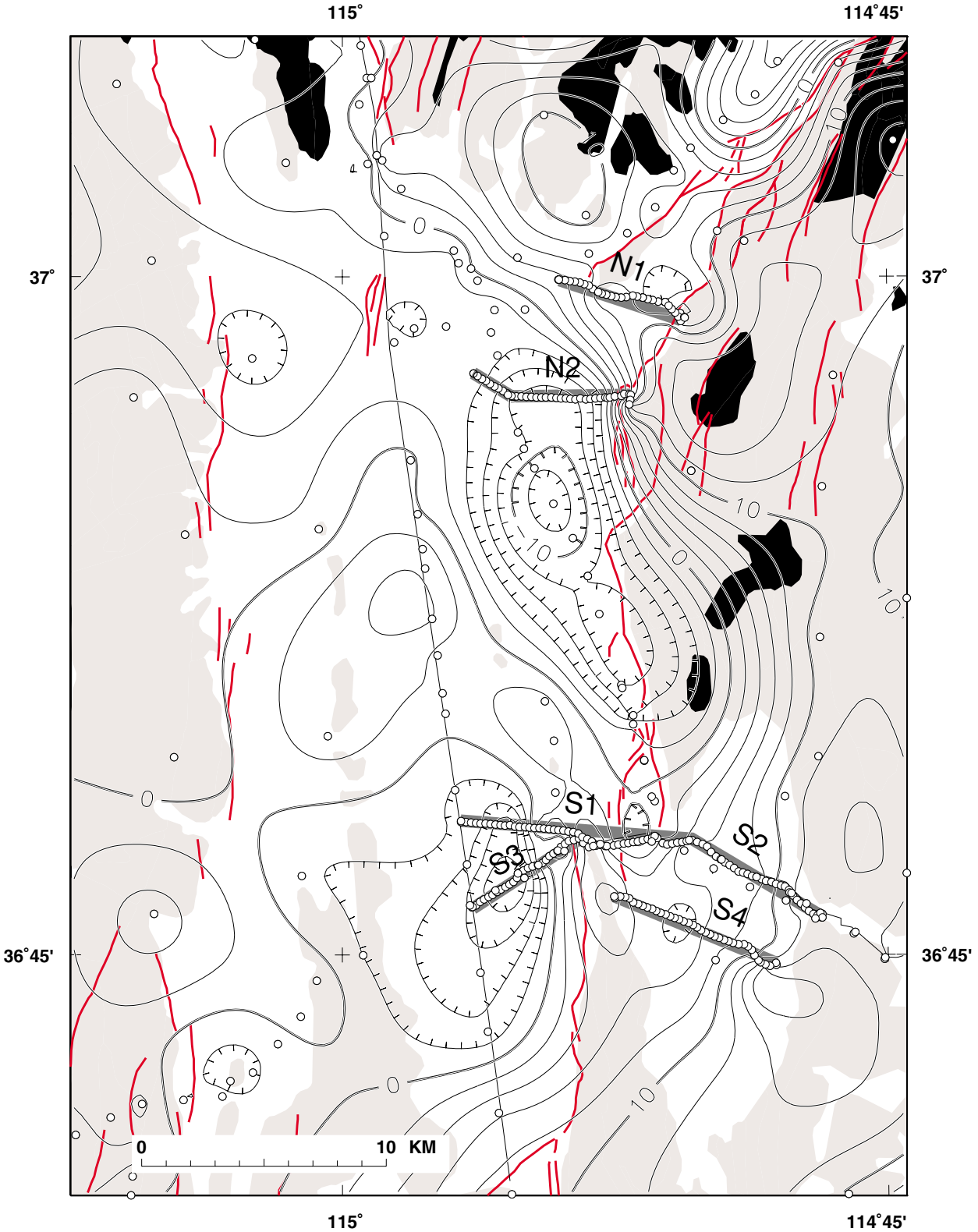



Figure 2. Map showing isostatic residual gravity of Coyote Spring Valley and vicinity. Contour interval = 2 mGal. Open circles show gravity stations. Gray bands labelled N1-N2 and S1-S4 are detailed gravity profiles that were modeled to define basin shape. Red lines indicate faults mapped by Dohrenwend and others (1996). See figure 1 for geology and culture. Refer to Plate 1 for larger scale presentation of these data.

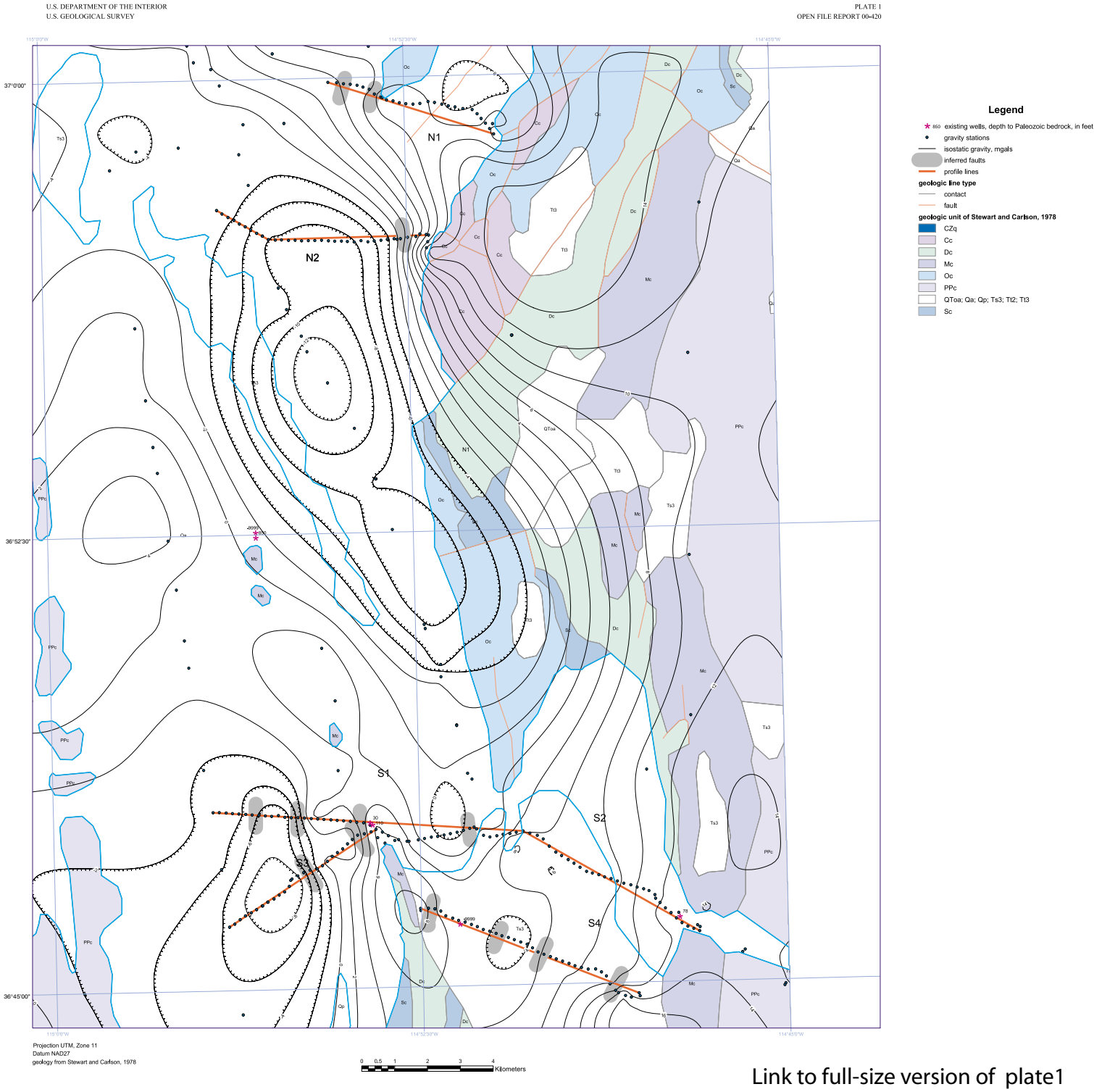
surrounding the study area (and presumably the floors of the intervening basins) are composed primarily of Paleozoic carbonate rocks (Stewart and Carlson, 1978) which typically have densities of 2.7 g/cm$^3$ or greater. The basins are filled primarily with Miocene tuffaceous sedimentary rocks (with minor tuff) and Quaternary alluvium. These basin fill deposits are typically much lower in density than the Paleozoic carbonate rocks with which they are in contact. Because of the large density contrast between the basin fill and the surrounding carbonate rocks, gravity techniques are well suited for defining the subsurface shapes of the basins and the geometries of the faults that bound the basins.

Previous geophysical work relevant to the present study are limited. Kane and others (1979) and Healey and others (1981) published gravity maps containing about 50 measurements in the vicinity of Coyote Spring Valley. Although more recent compilations more than doubled the number of measurements (Ponce, 1997), the coverage remained too sparse for the purposes of the present study. Geophysical logs for 8 wells in the Coyote Springs Valley area, including 4 wells drilled by the U.S. Air Force as part of the Nevada-Utah MX missile-siting investigation, contain lithologic, density, and electrical information (Berger and others, 1988). Saltus and Jachens (1995) examined the shape and distribution of basins throughout the Basin and Range Province by inverting regional gravity data to yield the thickness of Cenozoic deposits. However, their spatial resolution (2 km) is too coarse to provide useful local information for the present study. Carpenter and Carpenter (1994) analyzed seismic reflection profiles in southern Nevada and surrounding areas, one of which coincides with one of the southern gravity profiles included in this study. This seismic reflection profile provides a valuable check and confirmation of the gravity interpretations.

## DATA COLLECTION AND REDUCTION

224 gravity measurements, spaced 200 m (660 ft) apart, were taken along 5 profiles (fig. 2 and plate 1). Measurement locations were determined using a Trimble 1440 RTK (real-time kinematic) Global Positioning System (GPS) to record longitude, latitude, and elevation. Locations were recorded relative to GPS base stations located on local benchmarks. Benchmarks were located horizontally using Rockwell PLGR GPS units, which have an uncertainty of 7 m (23 ft). The vertical datum was provided by the elevation posted on the benchmarks, which gave elevation to the nearest foot. The Trimble RTK System typically has a relative error of 5 to10 cm (2-4 in) in the horizontal direction and 10-20 cm (4-8 in) in the vertical direction. Therefore, the absolute locations of the gravity observations have uncertainties of at least 7 m (23 ft) horizontally and 0.3 m (1 ft) vertically, but have smaller uncertainties in the relative positions and elevations of data along each profile. The relative positional uncertainties are the important ones for defining the shapes of the basins.

# Page-size version of plate 1




Link to full-size version of plate1

Isostatic Gravity Anomaly for the Coyote Spring Valley Area

Gravity data were collected during May 2000 using LaCoste and Romberg gravity meter G17c. All gravity data were tied to a gravity base station, GLEN, established at the Glendale Hotel in Glendale, NV. GLEN has a value of 979,682.63 mGal based on ties to LVGS, a gravity base station in front of the U.S. Geological Survey office in Las Vegas, NV (observed gravity 979,593.62 mGal).

Gravity data were reduced using the Geodetic Reference System of 1967 (International Union of Geodesy and Geophysics, 1971) and referenced to the International Gravity Standardization Net 1971 gravity datum (Morelli, 1974, p. 18). Gravity data were reduced to isostatic residual gravity anomalies using standard procedures (e.g. Telford and others, 1976) with a reduction density of 2.67 g/cm$^3$ and include earth-tide, instrument drift, free-air, latitude, Bouguer, curvature, and terrain corrections. An isostatic correction, using a sea-level crustal thickness of 25 km (16 mi), an upper crustal density of 2.67 g/cm$^3$, and a mantle-crust density contrast of 0.40 g/cm$^3$, was applied to the gravity data to remove long-wavelength gravity anomalies resulting from isostatic compensation of the topography by deep density distributions. The resulting isostatic residual gravity anomalies reflect, to first order, density variations within the middle and upper crust (Simpson and others, 1986).

Terrain corrections were computed to a radial distance of 167 km (104 mi) and involved a 3-part process: 1) Hayford-Bowie zones A and B with an outer radius of 68 m (223 ft) were estimated in the field with the aid of tables and charts; 2) Hayford-Bowie zones C and D with an outer radius of 590 m (1936 ft) were computed using a 30-m (100-ft digital elevation model; and 3) terrain corrections from a distance of 0.59 km (1936 ft) to 167 km (104 mi) were calculated using a digital elevation model and procedure by Plouff (1977). Total terrain corrections for stations measured during this study range from 0.24 to 3.73 mGal, averaging 1.14 mGal. 95% of the terrain corrections are less than 2 mGal. Uncertainties in the total terrain corrections, based on experience in other areas of Nevada, are estimated to be about 10% of the total correction. Because most of the gravity measurements were made far from the rugged topography that results in large terrain corrections, we estimate the uncertainty in terrain corrections for typical observations in this survey to be less than 0.2 mGal.

The reduced gravity data collected during this study are presented in Appendix 1. We estimate that the total uncertainty associated with these data, based on uncertainties in observed gravity (from meter drift and calibration uncertainties), horizontal position, elevation, and terrain correction, to be typically less than 0.3 mGal, although slightly larger uncertainties correspond to measurements with large terrain corrections (Appendix

1). These uncertainties are substantially smaller than the gravity anomalies associated with the basins, typically on the order of 5.0-10.0 mGal, and do not limit the modeling of the gravity anomalies in terms of basin structure.

The isostatic residual gravity field of the study area, as defined by our new data and all other existing data, is shown in figure 2 and on plate 1. As expected, the valleys are characterized by gravity lows (associated with the low-density deposits contained in them) and the surrounding ranges are characterized by gravity highs.

**DENSITY DATA**

Sixteen samples were taken at several outcrops (fig. 1) and measurements of sample density were made in the laboratory. With 1 exception the samples are Paleozoic carbonate rocks, which exhibit a mean density of 2.70 g/cm$^3$. The density of Quaternary alluvium was not measured directly, but was inferred to be approximately 2.15 g/cm$^3$ based on density logs in shallow wells within the study area (Berger and others, 1988). Densities of older and deeper basin-filling deposits have not been measured locally within the study area, but have been estimated region-wide (Saltus and Jachens, 1995; Jachens and Moring, 1990), and indirectly measured in a deep well in Morman Mesa 50 km (30 mi) to the east (Langenheim and others, 2000).

**DEPTH TO PALEOZOIC ROCKS**

We combined the gravity data collected during this study with existing data to estimate the areal form and distribution of basins in order to provide a regional framework within which to interpret the detailed gravity profiles. We used an iterative gravity inversion method that combines the gravity data with exposed geology, drill hole information, and other geophysical data to estimate the thickness of basin-filling deposits. The method used is an updated version of the method developed by Jachens and Moring (1990) that incorporates additional point data where the basin-fill thickness is known. The method partitions the gravity field into two components, one caused by variations in the thickness of the low-density basin fill, and the other caused by variations of density within the underlying Paleozoic rock. The 'basin-fill' component, together with an assumed vertical variation of density within the basin fill, are inverted to produce a 3-dimensional image of the basins. The method is iterative, successively yielding improved approximations to the shapes of the basins while simultaneously accounting for the gravity field variations caused by density variations within the Paleozoic rock and those caused by the lateral effects of low density basin deposits at locations in the surrounding ranges. For details of this method, the reader is referred to Jachens and Moring (1990) and Saltus and Jachens (1995).

The results of this inversion for Coyote Spring Valley and vicinity are shown in figure 3. The results show two deep basins (the northern crossed by profile N2 and the southern crossed by profiles S1 and S3) beneath the axis of Coyote Spring Valley, both reaching maximum depths greater than about 1 km (3300 ft). The deepest parts of both basins are aligned north-south and are separated from each other by a NNW-trending, shallowly-buried, bedrock ridge that is the northward continuation of the Arrow Canyon Range. A smaller basin (maximum depth of about 500 m (1600 ft)) lies beneath the valley containing Dead Man Wash and part of Pahranagat Wash, and appears to be the southern continuation of the northern basin beneath Coyote Spring Valley.

The general shapes and locations of the basins are reasonably well constrained by the gravity data, but the details of the basins must be viewed with caution. Except along the detailed gravity profiles, gravity data are sparsely distributed and the resulting basin definition is poor at best. In particular, the southern part of the northernmost basin and the northern part of the Dead Man Wash basin are quite uncertain because of the absence of gravity stations in the Meadow Valley Mountains (fig. 2). A better distribution of gravity stations in the ranges would lead to an improved estimate of the depths of the basins. An interesting characteristic of the southernmost basin beneath Coyote Spring Valley is that the main basin edge (as defined by the abrupt increase in basin depth), does not lie along the western edge of the Arrow Canyon Range, but rather some 2-3 km (1.5-2 mi) west of the range front. The seismic reflection profile analyzed by Carpenter and Carpenter (1994) confirms the offset between the Arrow Canyon Range front and the basin boundary (presumably a normal fault). We do not have enough data to say whether the eastern edge of the northern basin also is systematically displaced westward relative to the range-front of the Meadow Valley Mountains, but the results from gravity modeling discussed in the next section suggest that the basin's edge is within about 1 km (0.6 mi) of the range front.

## INTERPRETATION OF DETAILED GRAVITY PROFILES

Gravity models were constructed along 5 profiles (N1-N2 and S1-S4 on figure 2) in order to examine the detailed cross-sectional shapes of the basins and the structures that bound them. A constant density contrast of –0.55 g/cm$^3$ was used for each model based on a density of 2.70 g/cm$^3$ for the Paleozoic carbonate rocks and a basin fill density of 2.15 g/cm$^3$, the average density of the alluvium measured in two wells near the study area (CSV-1 and CSV-3, in Berger and others, 1988). The results of this modeling are shown in figures 4-6.

Within the Basin and Range province, faults resulting from the Miocene crustal extension often are characterized by abrupt lateral changes in the thickness of Cenozoic basin fill of

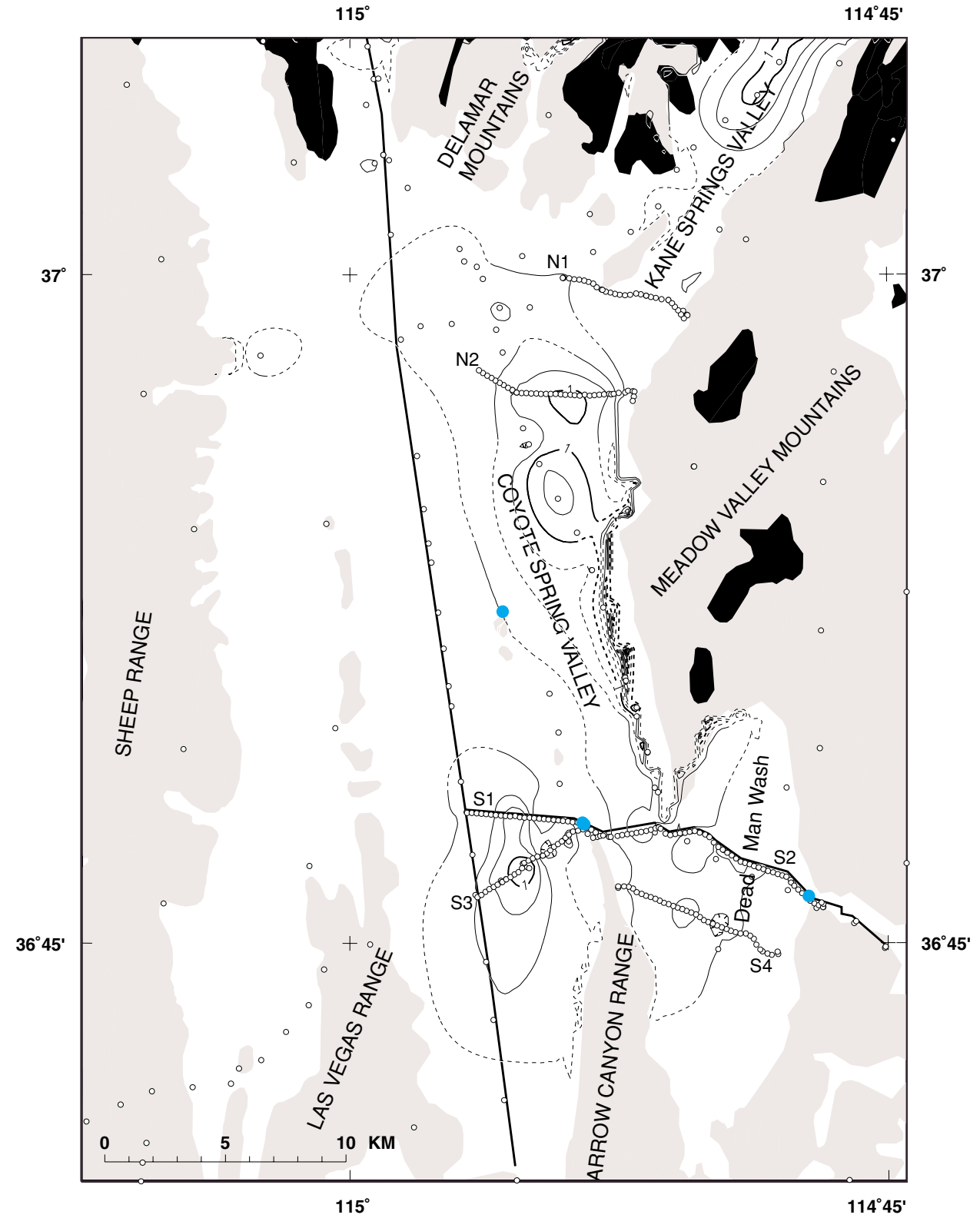



Figure 3. Basin thickness map of the study area. Contour intervals, 250 m, 1 km. Contours dashed where poorly constrained. White and black circles, gravity stations; blue dots, wells that penetrate pre-Cenozoic basement. Black areas have outcrops of Cenozoic volcanic rocks, gray areas have outcrops of Paleozoic rocks, and white areas indicate areas covered by Cenozoic basin fill.

a few hundred meters or more. This relationship is well illustrated along model-profile S1 (fig. 4) where four possible faults are identified in areas of abrupt lateral changes in the thickness of the basin fill. Three of these (identified by asterisks) correspond to faults identified by Carpenter and Carpenter (1994) on the basis of seismic reflection profiling and two (identified by open circles) correspond to faults mapped by Dohrenwend and others (1996). The fourth and westernmost possible fault in figure 4 lies beyond the western end of the seismic reflection profile.

Figure 5 shows gravity models along the two northern profiles, N1 and N2, and figure 6 shows two additional gravity models along southern profiles S3 and S4. Locations of abrupt lateral changes in the thickness of basin fill are identified as possible locations of faults on figures 5 and 6, and their locations in map view are shown on plate 1. A model along profile S2 yielded only a thin, relatively uniform layer of basin fill a few hundred meters thick, and showed no characteristic features that would suggest faults.

The models shown are based on an assumed density contrast of –0.55 g/cm$^3$ between Paleozoic rock and the basin fill. This density contrast is uncertain primarily because actual measurements of the density of the basin fill are few, and because the density of the fill in the deeper parts of the basin has not been measured locally. We estimate that these uncertainties could be as large as 0.1 g/cm$^3$ or about 20%. If the actual density contrast along any profile is smaller in magnitude than –0.55 g/cm$^3$, the actual depth to Paleozoic rock will be greater than that shown (roughly in proportion to the percentage error). If the actual density contrast is larger, then the depth will decrease. In general, however, the shape of the basin and the locations of abrupt lateral changes in the thickness of the basin fill will not change. Therefore, the locations of possible faults defined by the gravity modeling should not be affected by any reasonable uncertainty in the density contrast used to model the gravity data.

## DISCUSSION

Gravity surveys provide an effective method for defining the configuration of concealed Cenozoic basins in the vicinity of Coyote Spring Valley, and, based on a comparison between gravity modeling results and seismic reflection profiling along S1, detailed gravity profiles can be effective in identifying concealed faults. Although the subsurface configuration of the basins are well constrained along the detailed profiles of the present study, the gravity data throughout the rest of Coyote Spring Valley are too sparsely distributed to give more than a generalized image of the basins and their bounding faults. Additional gravity surveys could be used to refine the image of the basins and faults and to trace individual fault strands and establish their continuity. Analysis of aeromagnetic data over the study area in conjunction with the gravity field produced by the Paleozoic

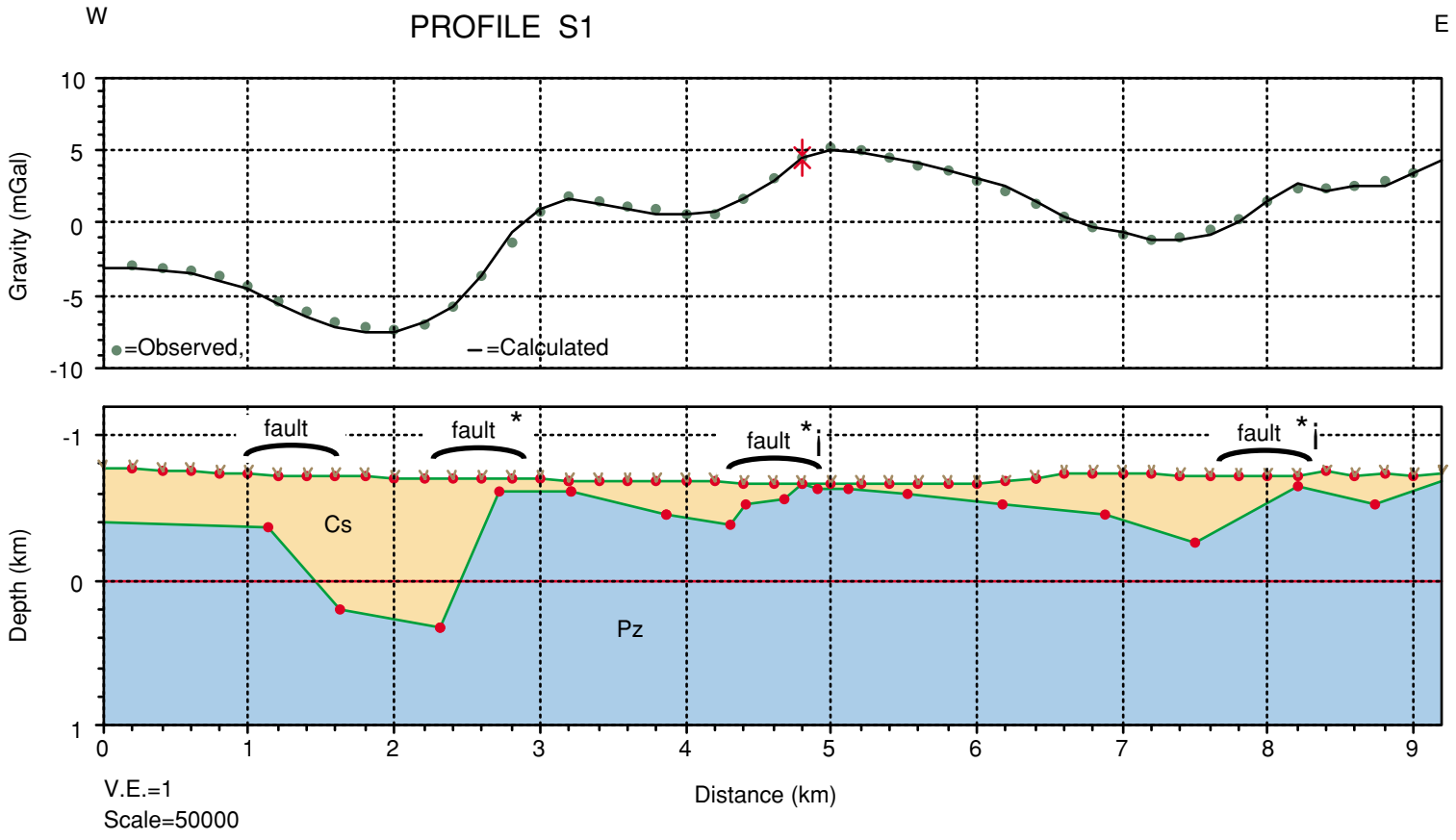



Figure 4. Gravity model along profile S1. Density contrast between Paleozoic bedrock and Cenozoic basin fill, -0.55 g/cm$^3$. Pz--Paleozoic rock; Cs--Cenozoic basin fill. Faults marked by asterisks correspond to faults identified by Carpenter and Carpenter (1994) on the basis of seismic reflection profiling and faults marked by open circles correspond to faults mapped by Dohrenwend and others (1996).

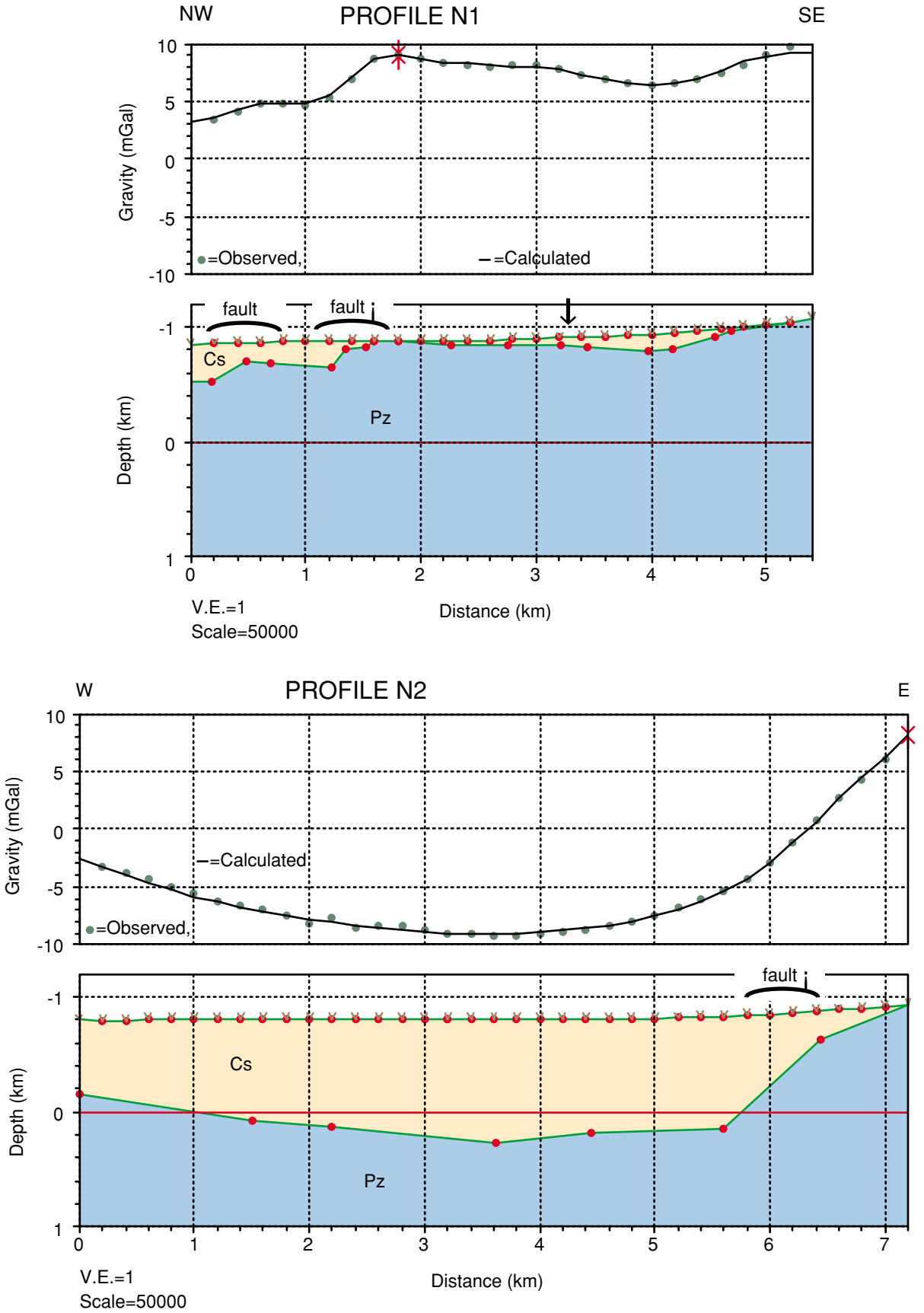



Figure 5. Gravity models along profiles N1 and N2. Density contrast between Paleozoic bedrock and Cenozoic basin fill, -0.55 g/cm$^3$. Pz--Paleozoic rock; Cs--Cenozoic basin fill. Faults marked by open circles correspond to faults mapped by Dohrenwend and others (1996). Arrow indicates location of fault shown by Stewart and Carlson, 1978.

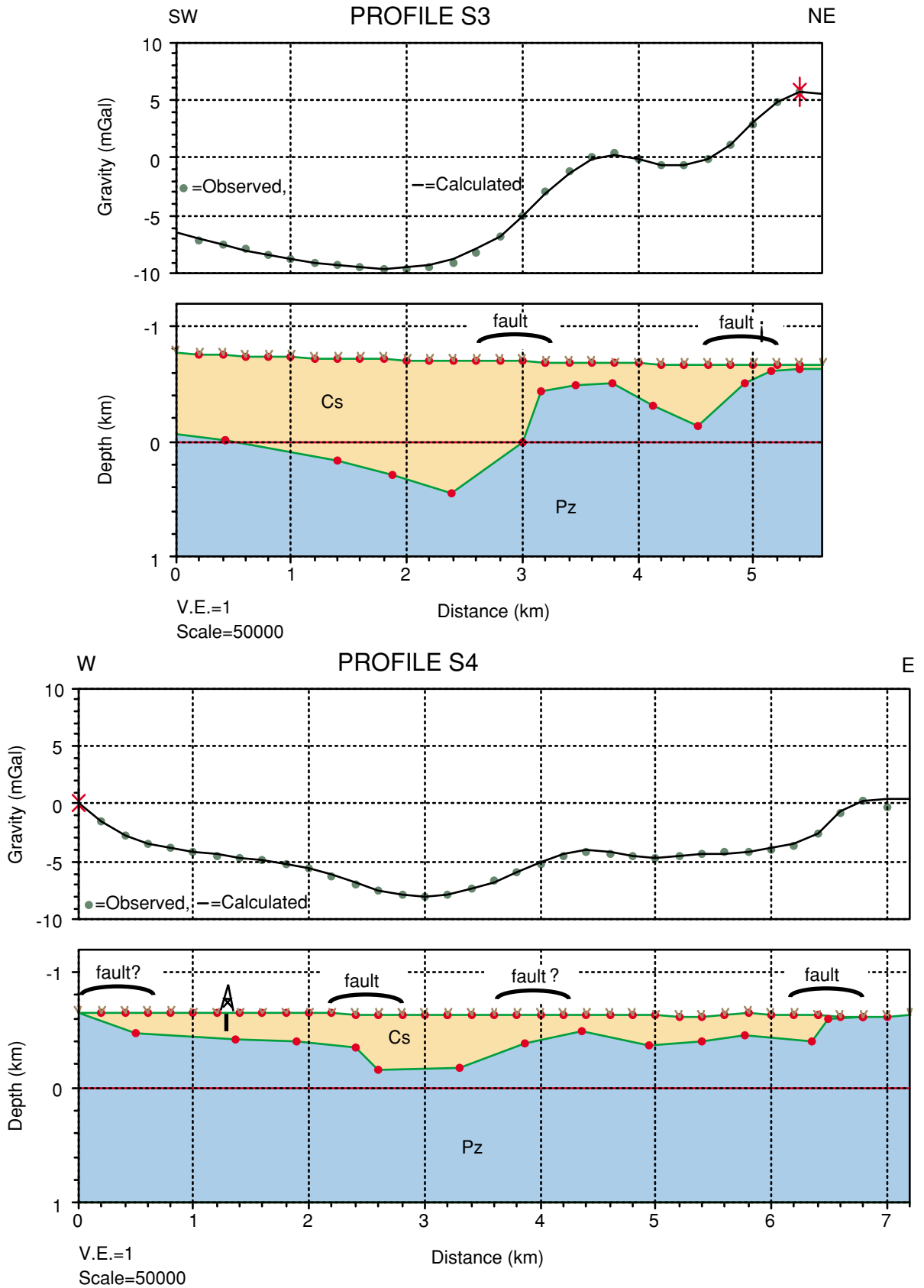



Figure 6. Gravity models along profiles S3 and S4. Density contrast between Paleozoic bedrock and Cenozoic basin fill, -0.55 g/cm$^3$. Pz--Paleozoic rock; Cs--Cenozoic basin fill. A linear, westward decreasing regional gradient was removed from profile S4 prior to modeling. Fault marked by an open circle corresponds to a fault mapped by Dohrenwend and others (1996). Well CSV-1 (Berger and others, 1988) is 765 ft deep and did not reach Paleozoic rock.

bedrock (a map that is an outgrowth of the basin-depth inversion) can yield additional information about the lithology and structures within the pre-Cenozoic rock. All of this information could serve as the basis for improving the hydrogeologic framework of the region which, in turn, could be used in a refined ground-water flow model.

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APPENDIX 1: Principal facts for new gravity stations in Coyote Spring Valley and vicinity.

Key to gravity file
Record 1 Station identifier
Record 2 Latitude (in degrees)
Record 3 Latitude (in minutes, to 0.01)
Record 4 Longitude (in degrees)
Record 5 Longitude (in minutes, to 0.01)
Record 6 Elevation (in feet, to 0.1)
Record 7 Observed Gravity (in mGal, to 0.01)
Record 8 Free Air Anomaly (in mGal, to 0.01)
Record 9 Simple Bouguer Anomaly (in mGal, to 0.01)
Record 10 Inner Zone Terrain Correction (in mGal, to 0.01)
Record 11 Total Terrain Correction (in mGal, to 0.01)
Record 12 Complete Bouguer Anomaly (in mGal, to 0.01)
Record 13 Isostatic Residual Anomaly (in mGal, to 0.01)

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GLEN | 36 | 3996 | 114 | 3409 | 15030 | 97968263 | -5181 | -10307 | 0 | 24D | -10342 | 702 |
| WC001 | 36 | 5742 | 114 | 5546 | 26017 | 97960458 | -5178 | -14051 | 6 | 70D | -14074 | -815 |
| WC002 | 36 | 5943 | 114 | 5110 | 31515 | 97958799 | -1958 | -12707 | 7 | 194D | -12620 | 636 |
| WC002 | 36 | 5943 | 114 | 5110 | 31556 | 97958794 | -1925 | -12687 | 7 | 193D | -12602 | 654 |
| WC003 | 36 | 5919 | 114 | 5069 | 33539 | 97957767 | -1052 | -12491 | 93 | 373D | -12231 | 988 |
| WC004 | 36 | 5902 | 114 | 5067 | 34375 | 97957316 | -693 | -12417 | 45 | 355D | -12176 | 1025 |
| WC005 | 36 | 5911 | 114 | 5075 | 33522 | 97957763 | -1061 | -12494 | 36 | 320D | -12286 | 925 |
| WC006 | 36 | 5920 | 114 | 5083 | 33002 | 97958009 | -1317 | -12573 | 22 | 273D | -12411 | 813 |
| WC007 | 36 | 5928 | 114 | 5092 | 32424 | 97958315 | -1566 | -12624 | 13 | 239D | -12495 | 738 |
| WC008 | 36 | 5936 | 114 | 5100 | 31849 | 97958631 | -1802 | -12665 | 10 | 219D | -12553 | 693 |
| WC009 | 36 | 5945 | 114 | 5129 | 31159 | 97958995 | -2100 | -12727 | 5 | 163D | -12671 | 593 |
| WC010 | 36 | 5948 | 114 | 5145 | 30819 | 97959178 | -2241 | -12752 | 5 | 145D | -12713 | 560 |
| WC011 | 36 | 5950 | 114 | 5159 | 30500 | 97959394 | -2328 | -12730 | 4 | 131D | -12704 | 577 |
| WC012 | 36 | 5953 | 114 | 5172 | 30228 | 97959637 | -2345 | -12654 | 3 | 121D | -12638 | 652 |
| WC013 | 36 | 5956 | 114 | 5187 | 29920 | 97959889 | -2387 | -12591 | 3 | 111D | -12584 | 713 |
| WC014 | 36 | 5958 | 114 | 5200 | 29679 | 97960135 | -2370 | -12493 | 3 | 105D | -12491 | 812 |
| WC015 | 36 | 5955 | 114 | 5217 | 29366 | 97960349 | -2446 | -12462 | 2 | 100D | -12464 | 844 |
| WC016 | 36 | 5954 | 114 | 5231 | 29126 | 97960458 | -2561 | -12495 | 1 | 96D | -12501 | 811 |
| WC017 | 36 | 5955 | 114 | 5246 | 28968 | 97960578 | -2591 | -12471 | 1 | 91D | -12481 | 837 |
| WC018 | 36 | 5957 | 114 | 5259 | 28891 | 97960631 | -2614 | -12467 | 1 | 87D | -12481 | 843 |
| WC019 | 36 | 5960 | 114 | 5272 | 28797 | 97960707 | -2630 | -12452 | 2 | 84D | -12468 | 862 |
| WC020 | 36 | 5962 | 114 | 5285 | 28707 | 97960783 | -2642 | -12433 | 3 | 83D | -12451 | 886 |
| WC021 | 36 | 5967 | 114 | 5297 | 28723 | 97960857 | -2560 | -12356 | 6 | 82D | -12375 | 972 |
| WC022 | 36 | 5972 | 114 | 5310 | 28568 | 97960754 | -2816 | -12560 | 3 | 77D | -12583 | 771 |
| WC023 | 36 | 5966 | 114 | 5294 | 28821 | 97960798 | -2526 | -12355 | 6 | 81D | -12375 | 969 |
| WC024 | 36 | 5980 | 114 | 5320 | 28535 | 97960575 | -3038 | -12770 | 3 | 75D | -12795 | 568 |
| WC025 | 36 | 5984 | 114 | 5333 | 28763 | 97960332 | -3072 | -12882 | 1 | 69D | -12914 | 457 |
| WC026 | 36 | 5987 | 114 | 5345 | 28550 | 97960465 | -3144 | -12881 | 4 | 71D | -12911 | 467 |
| WC027 | 36 | 5989 | 114 | 5359 | 28117 | 97960764 | -3255 | -12844 | 6 | 74D | -12870 | 514 |
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| WC141 | 36 | 4758 | 114 | 5134 | 23359 | 97962578 | -4134 | -12101 | 16 | 78D | -12109 | 230 |
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WC228 36 5774 114 5616 26046 97960899 -4756 -13639    1   65D -13667  -355
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